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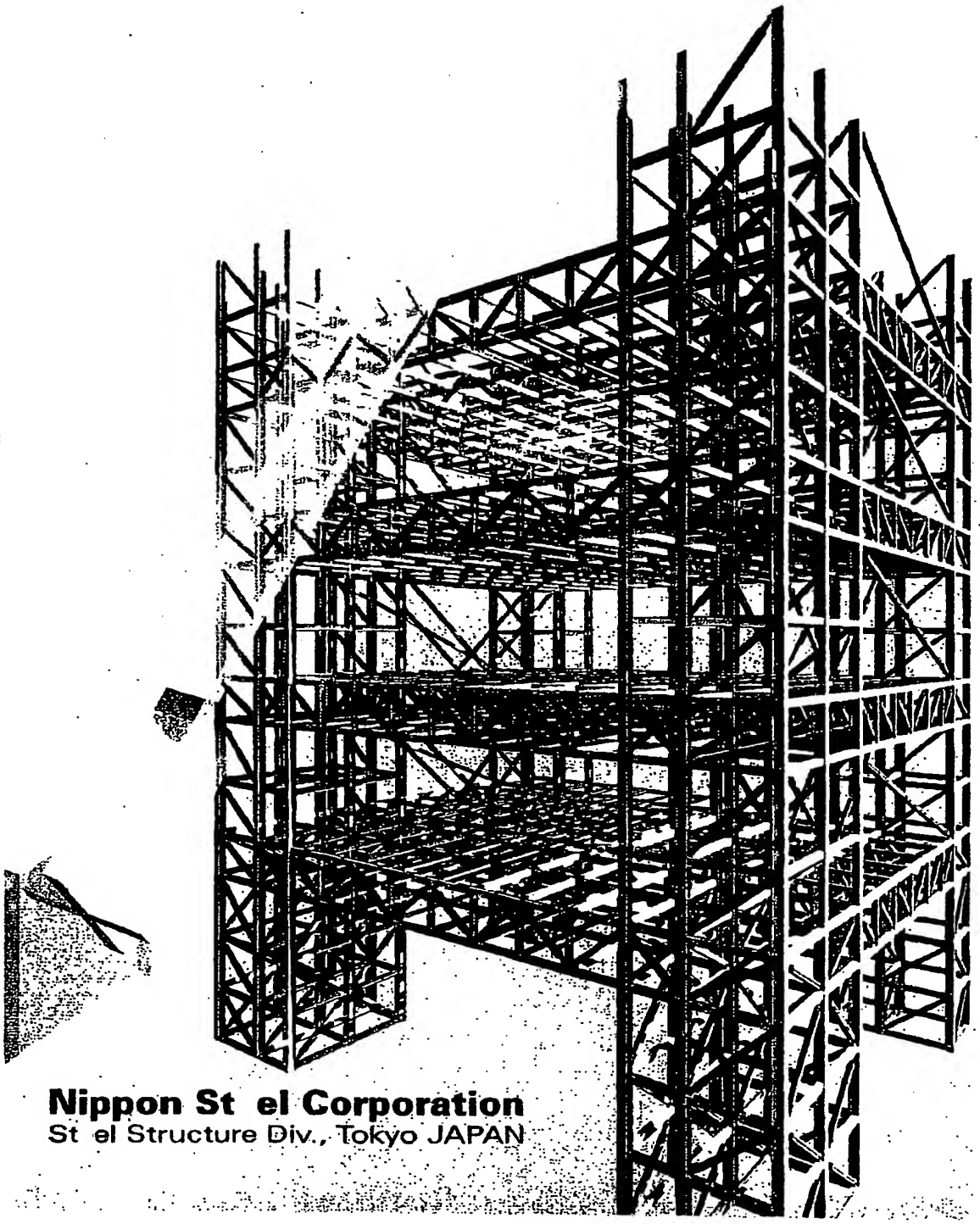
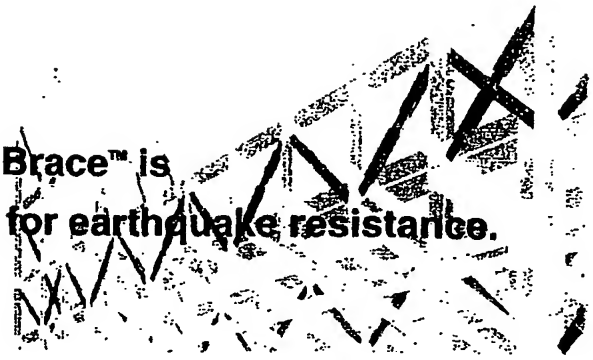
Unbonded Brace™

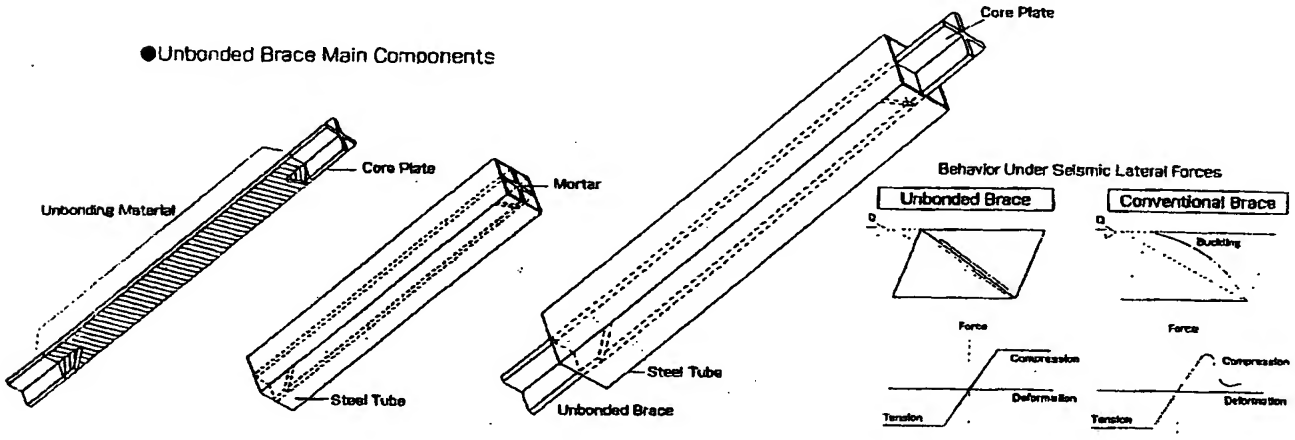


Nippon St el Corporation
St el Structure Div., Tokyo JAPAN

Nippon Steel Corporation's Unbonded Brace™ is a high-performance structural element for earthquake resistance.



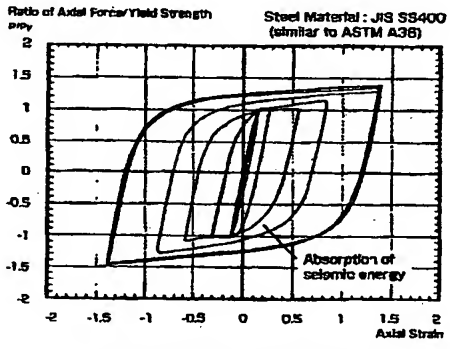
●Unbonded Brace Main Components



Unbonded Brace™ Concept

Nippon Steel Corporation's Unbonded Brace is a structural brace element consisting of a steel core plate surrounded by mortar and enclosed in a steel tube. It provides very stable, repeatable and **symmetric** hysteretic behavior in the inelastic range and does so **without buckling.**

A membrane called the unbonding material, between the core plate and the mortar, ensures that axial forces in the core plate do not transfer to the mortar and the steel tube. This ingenious combination of components produces a seismic structural element with stable and symmetric tension-compression hysteretic behavior.



Unbonded Brace Hysteretic Behavior

High Performance and Quality at an Economical Price

Prior to shipment

Unbonded Braces are manufactured to the highest quality standards. The thickness of the unbonding material layer is very tightly controlled in the fabrication process to ensure a uniform clearance between the core plate and the surrounding mortar. This, along with other key details, ensures that yielding of the brace core plate is uniform along its length, and that Unbonded Braces achieve higher performance than any other comparable structural elements. The Unbonded Brace is an efficient combination of economic materials: steel and concrete mortar.

BCJ Approval*

*License Number BCJ-S-1278 (The Building Center Japan is part of the Ministry of Construction, similar in function to ICBO)

Nippon Steel's Unbonded Brace received a "BA" classification approval from BCJ as both a seismic control member and a structural element, and as a result can be used to achieve designs that are more economical than regular structural systems.

(Japanese patents issued; U.S. patent pending)

The essence of the Unbonded Brac ™ is a brace that do sn't b[illegible]ckle, is highly ductile, and v ry eff ctively absorbs seismic n rgy.

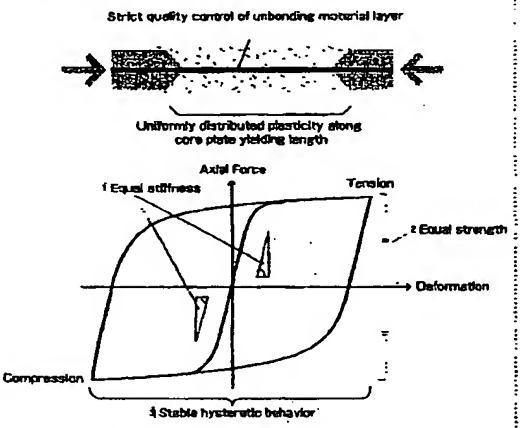
Unbonded Brace™ Performance

(1) Hysteresis loops in tension and compression have equal strength and rigidity, in the pre- and post-yield ranges.

(2) In full-scale shaking table dynamic tests, Unbonded Braces show stable hysteretic behavior at deformations up to ±7% brace axial strain.

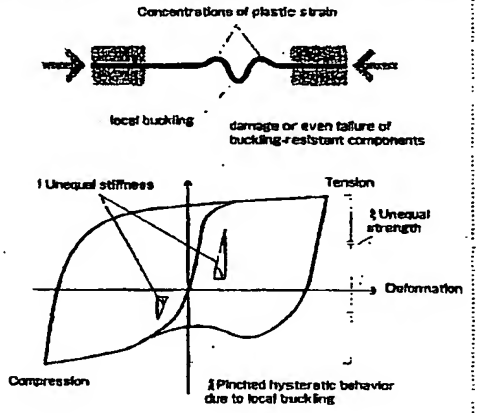
(3) In low-cycle fatigue tests, Unbonded Braces maintain stable behavior for over 200 cycles at an axial strain of ±0.75% (approximately equal to 1% story drift).

●Nippon Steel's Unbonded Brace



①Same stiffness in tension and compression
②Same strength in tension and compression
③Stable and symmetric hysteretic behavior in tension and compression

●A buckling-restraint brace with ineffective confinement

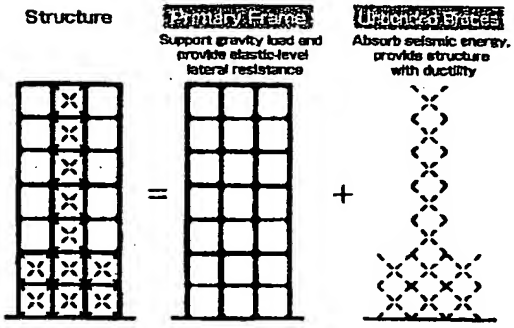


Application to "Damage Tolerant" Structures

Unbonded Braces are designed to operate in the plastic range under seismic loading, and therefore earthquake energy is concentrated in the Unbonded Braces while the primary structural frame is designed to remain essentially elastic. As a result, an economical design can be achieved for the primary frame and it can remain undamaged, even after a severe earthquake. If necessary, only the Unbonded Braces need to be replaced after a severe earthquake, achieving a higher level of safety for the building and easier post-earthquake recovery.

●Damage Controlled Design

	Conventional Design	Damage Controlled Design	
	Primary Frame		
Small Earthquake	Elastic	Elastic	Plastic (Energy Absorption)
Severe Earthquake	Plastic (Plastic at Beam Ends)	Elastic	Plastic (Energy Absorption)



Type of Unbonded Brace	Type of Core Plate	Material Specification
Standard Type	Flat Plate (-)	●JIS SS400 (similar to ASTM A36) ●JIS SM490 (similar to ASTM A572/50) ●JIS SM520 (similar to ASTM A572/60) ●JIS SN400 (similar to ASTM A36, but with lower and upper limits on Fy and Fu) ●JIS SN490 (similar to ASTM A992/50)
	Cruciform (+)	

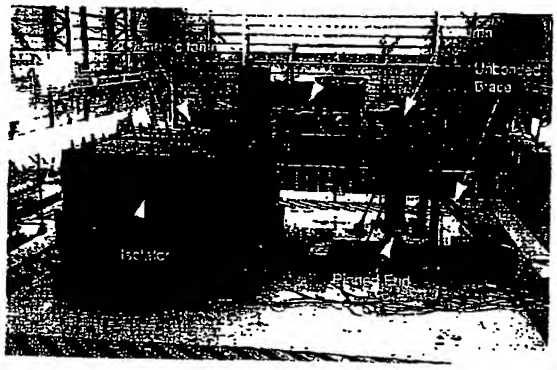
The xc llent performance of Unbond d Braces™ has been d monstrat d in numerous test programs.

Full-Scale Dynamic Shaking Table Tests*

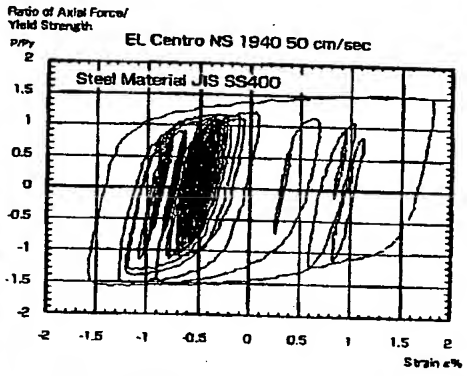
*Building Research Institute Laboratory, Tsukuba, Japan

The JMA Kobe Observatory ground motion (Kobe, 1995) was applied at maximum velocities from 10 to 70 cm/s (4 to 27.6 in/s), and the Unbonded Brace showed stable hysteretic behavior for axial strains as high as 7.5%.

The El Centro ground motion (California, 1940) was applied at maximum velocities from 5 to 90 cm/s (2 to 35.4 in/s) and the Unbonded Brace showed stable hysteretic behavior for axial strains as high as 7.2%.



●Typical Result, Full-Scale Shaking Table Test

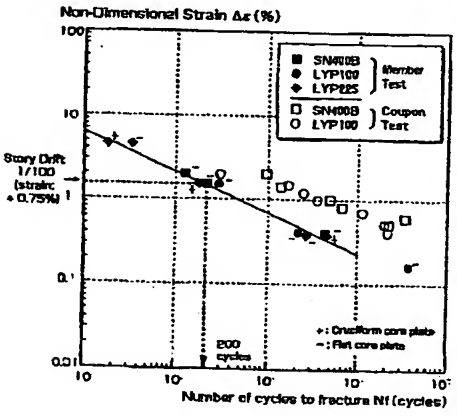


Maximum story drift (tension: 1/57, compression: 1/65)

Fatigue Resistance

Under low-cycle fatigue testing, Unbonded Braces show stable hysteretic behavior for 200 cycles under a deformation corresponding to 1% story drift.

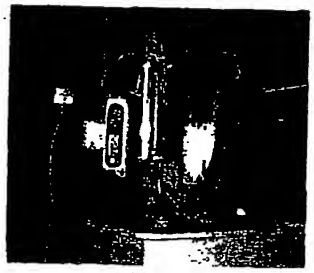
●Low-Cycle Fatigue



Response Measurement Device

Optional Measurement Device: Maximum Deformation Meter

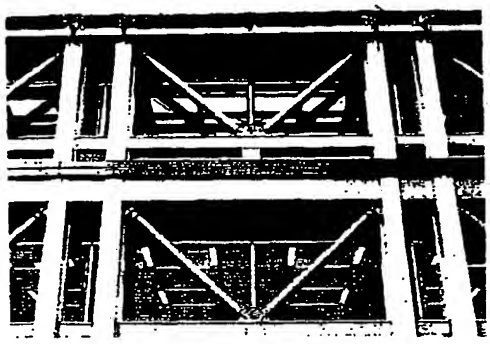
If it is required to monitor the seismic behavior of installed Unbonded Braces, Nippon Steel optionally provides a simple mechanical device (requiring no electrical power for operation) that records the maximum brace deformation in an earthquake.



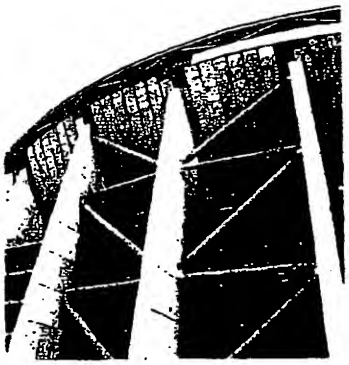
Unbond d Braces™ hav be n applied to numerous large and high-quality structur s.

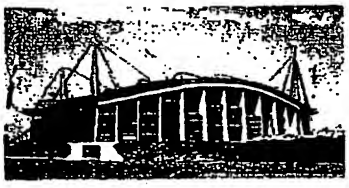
Unbonded Brace Applications in Japan (through 2000)

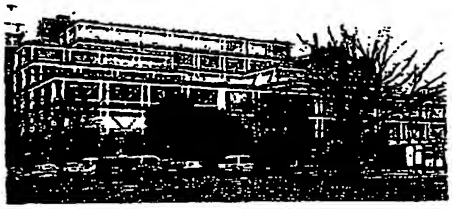
High-rise Buildings (over 15 stories)	90 buildings
Low-rise Buildings (less than 15 stories)	70 buildings
Total	Over 160 buildings



● **Exposed Braces with Cast End Connections**
2000
Toyota Stadium, Aichi
Design: K. Kurokawa, Ove Arup Japan

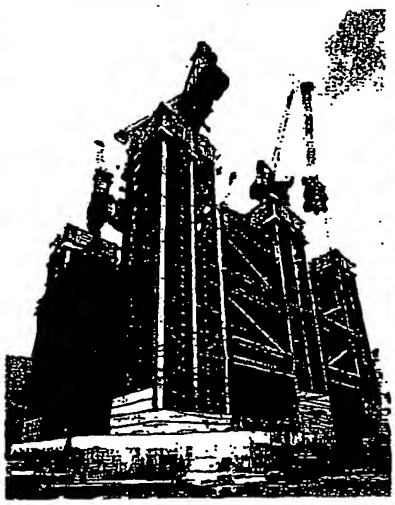




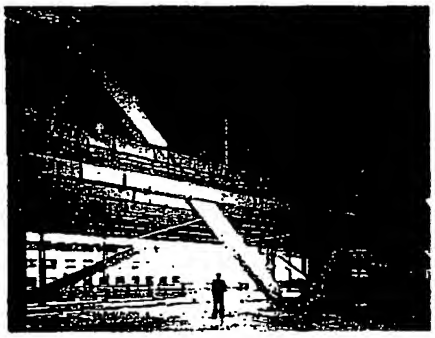


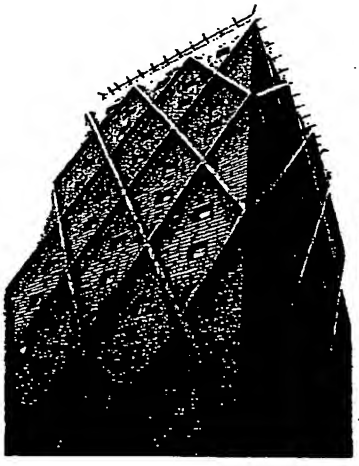
● **Exposed, Fire Protected, Welded Connections and Circular Tube Unbonded Braces**
1991
I. K. Building, Tokyo
Design: Nikken Sekkei

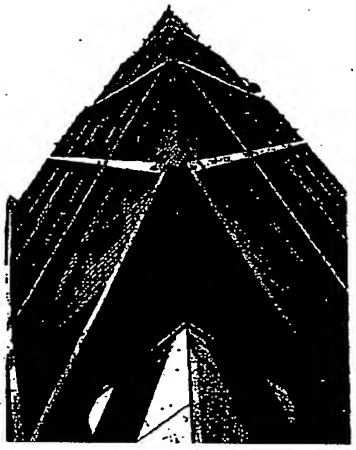
●**Car Parking Structure**
1997
Minatomachi Plaza, Kanagawa
Design: Endo Associates



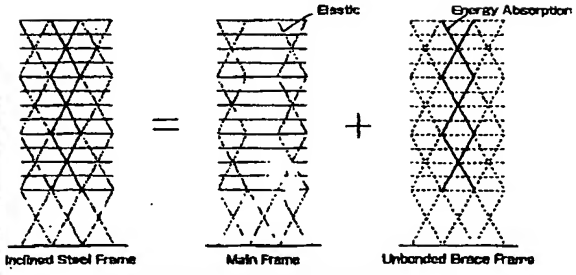
●**Very Large Unbonded Braces** (22 m, 72.5 ft long)
1998
Osaka International Convention Centre, Osaka
Design: K. Kurokawa, Ove Arup Japan







●**Damage Tolerant Design Application**
1997
Sankyo Tokyo Headquarters, Tokyo
Design: Plantec, Alpha Structural Design



Braced Frame Structural System

Material Specifications

Core Plate	JIS SS400 (similar to ASTM A36) JIS SM490 (similar to ASTM A572/50) JIS SM520 (similar to ASTM A572/60) JIS SN400 (similar to ASTM A36, but with lower and upper limits on Fy and Fu) JIS SN490 (similar to ASTM A992/50) * Minimum core plate thickness is 19mm (3/4 in.).
Steel Tube	JIS STKR400, STK400, Thickness : 3.2 mm to 16 mm Width or Diameter : 100 to 500 mm (larger sizes are possible upon request)
Mortar	As per Nippon Steel Technical Specification
Design of Steel Tube	As per Nippon Steel Technical Specification

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